

Chapter 17

Toxicology

"All substances are poisons: there is none which is not a poison. The right dose differentiates a poison from remedy."-
Swiss Physician Paracelsus (1493-1541)

1. Definition, Nature and Principles of Poison

Toxicology is the scientific study of adverse effects of chemicals in living organisms. It deals with poisons and their effect. Forensic toxicology deals with medical and legal aspects of the harmful effects of chemicals on human being. It studies properties, actions, toxicity, fatal dose, detection, and treatment of poisons.

Toxicology is the study of the effects of toxins, as well as other chemical substances, on living organisms; whereas, 'Toxinology' is the study of the toxins, poisons, and venoms from plants (poisonous plants), animals (venom of snakes, spiders, bees etc.), and microbes (bacterial and fungal toxins). In short, toxicology is the science that deals with toxicity or toxic effect of any substance.

The term 'Toxin' denotes biologically-derived chemical substance that causes physiological harm to an organism. The term 'Poison' denotes- either a singular toxin or mixture of toxins delivered passively, by means of absorption, inhalation, or ingestion, to another organism that causes illness,

impairment, or other biological harm at a physiologically-dependent amount for the purpose of defense; often acquired exogenously. And the term 'Venom' denotes- complex cocktail of toxins delivered through a specialized delivery mechanism from one organism to another for the purpose of predation, defense, digestion, competition, or other benefit of the organism, delivering the venom; often acquired endogenously.

It is hard to define poison because i) a substance which is harmless in small quantities may act as poison and cause death when taken in large amount and ii) bacterial toxins are not regarded as poisons in ordinary sense of the term.¹ Generally, poison is a substance (solid, liquid or gaseous) which, when administered to a living human body, is capable of producing ill health or death. There is no exact difference between a medicine and a poison because a medicine in a large dose is a poison and a poison in therapeutic or a small dose may be a medicine. For example, chloral hydrate in small form of 300 mg is medicine when used as a hypnotic. Simultaneously, higher dose of 3 gram is poison and tended to be used to a rape victim or helpless robbery victim. Thus, poison could be defined as a substance that usually kills, injuries or impairs either human being or any other living organism through its chemical action.²

In law, the real difference between a medicine and a poison is the intent with which it is given. If the substance is administered with the intention to provide relief or save life, it is a medicine but if it is given with intention to cause bodily/mental harm, it is a poison.³ Any substance having poisonous character has dual characters either useful for saving

1 Dr. K.S. Narayan Reddy, The Essentials of Forensic Science and Toxicology, 425 (21st ed. 2002).

2 Available at <https://www.merriam-webster.com/dictionary/poison> (accessed on 24 April 2018)

3 C.K. Parikh's Textbook of Medical Jurisprudence, Forensic Science and Toxicology 8.2 (6th ed. 1999).

life if properly administrated in order to cure diseases or damaging life by impairing body organs.

Principles of toxicology are important because they explain the effect of poisons in human body. The dose of poison administered, defense activities showed by the body, degree of harm produced by the poison over the body etc. are evaluated based on the practiced principle in the field of toxicology. An effect of poison varies in accordance to the built of person, nature of poison, dose of poison and time lapsed after administration of poison. Generally, forensic toxicology is concerned with two major principles:

- a) Principle of Toxicodynamics: Toxicodynamics deals with study of any action and reaction within the organism after intake of poison. It describes of process or mechanism how the poison affects any organs, tissues, and at cellular and molecular levels. The level of effect produced by any harmful chemical in human body is studied under it. It helps to determine whether the poisoning is acute, chronic or of some other level. Different factors such as dose of chemical, duration of exposure, presence of any catalyst substance in stomach of the victim etc. are useful to study. Different groups of poison have different effects and show different symptoms. For instance, symptoms of organophosphates show salivation, lacrimation, urination, diarrhea, gastritis, emesis, small pupils.⁴
- b) Principle of Toxicokinetics: When poison enters into our body, our body shows defense mechanism such as vomiting. It refers the process of absorption, distribution, elimination and metabolism of toxin in living organism including human being. Study of toxicokinetics attempts to resolve following questions:

⁴ Moore C (2009). Children and Pollution: Why Scientists Disagree. Oxford University Press. pp. 109-112.

- What is the route of administration of poison/how the xenobiotic (foreign chemical substance) enters the body?
- How much the xenobiotic is distributed in the body such as pancreas, intestines, kidney, lungs, and other vital viscera?
- What was the body reaction to xenobiotic such as vomiting, diarrhea, internal burn feeling or allowing body function?
- What is done or is to be done to remove xenobiotic from the body?

The toxicity of any xenobiotic substance is determined by both toxicodynamics and toxicokinetics factors. If the effect of toxicodynamics suppresses toxicokinetics, one will die or produce ill health. If toxicokinetics is active then the poison may not affect the person and life could be saved. The whole process of treatment to patient depends upon this principle of struggle between toxicodynamics and toxicokinetics. Antidote given to patient activates toxicokinetics thereby minimizing the effect of poison. Thus, principles of toxicology are the basic foundation on the basis of which the whole treatment process of an intoxicated patient depends upon.

2. Classification of Poison

Modi has broadly categorized poisons in major three classes in accordance to major symptoms they produce such as corrosive, irritants and systemic poison.⁵

On the basis of nature of action produced by the poisons, they are broadly categorized into six different classes.⁶

5 P. Jaising Modi, Modi's Medical Jurisprudence and Toxicology 12 (B V Subramanyam eds, 22nd ed. 1999).

6 Supra note 4 at 8.2

Each poison within their groups has certain common nature and properties. They are:

1) Corrosive Poisons

Poisons under this class are corrosive in nature. Corrosive means they cause gradual wear/dissolution of human body by their chemical reaction. Corrosive poisons are both organic and inorganic in nature. Inorganic acids such as sulfuric acid, nitric acid, hydrochloric acid produce local injury such as burns and necrosis of impacted tissues. Strong alkalis may produce deep burn injury than acid.

Organic acid such as oxalic acid, carbolic acid have both local and remote action. If organic acids are administered in large volume, they act as corrosive. Vegetable base such as potassium, sodium carbonate also may act as corrosive.

Action of Corrosives (Symptoms)

Action of corrosive is mainly local on the tissue of the alimentary tract. Some of them are:

- Extraction of hydrogen oxide from the tissues
- Coagulation of cellular proteins, and
- Conversion of hemoglobin into haematin
- There may be signs of corrosive in the mouth, gum, lips, throat, oesophagus, stomach and abdomen.

Cause of death: The cause of death associated with corrosive poisoning may be primary shock, suffocation or perforation of stomach.

2) Irritant poisons

Very dilute solution of corrosives act as irritant. Irritant

poisons produce irritation showing pain in abdomen, vomiting and purging. It could be further classified as:

- a) Inorganic poisons: There are two types of it. They are:
- I. Metallic poison: Chronic metallic poisoning leads to struggle to such a lingering death, which is called as slow poisoning. Chemicals such as arsenic, lead, copper, zinc, thallium etc. fall under it.
 - II. Non-metallic poison: This class of poison includes chlorine, bromine, iodine, phosphorous etc.
- b) Organic poison: It has further two types:
- I. Vegetables: Vegetables produce inflammation, vesication, postulation and callous sores externally and symptoms of gastrointestinal irritation internally.
 - II. Animals: Animals such as cantharides, snakes, and scorpions etc. create poison. The symptoms of cantharides produce local irritation and irritation of gastrointestinal and genitourinary. Symptoms of snake and scorpions poisons are mainly local, neuro-toxic, haemotoxic and myotoxic.
- c) Mechanical Poison: Mechanical poisons are actually not poisons because they are not absorbed, but produce symptoms of irritant poisoning solely. They have mechanical myotoxic action on the part where they come to contact. Powered glass, pins, needles, and chopped hair etc. are the examples of mechanical poison.

Symptoms of Irritant Poisons

Following symptoms of irritant poisons may be seen:

- Cause gastroenteritis,
- Exerts marked depressant action after absorption

- Burning sensation at the site of contact such as mouth, throat and skin,
- Difficulty in swallowing,
- Severe pain in the intestine and intense thirst,
- Persistent vomiting
- Diarrhea is severe.

3) Neurotics

This group of poison has specific action on the nervous system, brain and spinal cord. Neurotic poisons can further be classified as:

Cerebral poisons: They mainly attack on brain causing delirium or narcotic effect. Poisons such as alcohol, ether, chloroform, chloral hydrate, *datura*, opium, cannabis, cocaine etc. fall under it.

Spinal poisons: Spinal poisons chiefly affect on spinal system causing stimulant or depressed effect. Tobacco, strychnine etc. are its example.

Cerebral-spinal poison: This poison affects both nervous system and spinal cord. Oleander is a good example of it. Physical appearances that are seen in the case of drug abuse are similar here.

4) Cardiac Poison

Poisons such as digitalis, oleander, aconite and nicotine are considered as cardiac poison. This type of poison creates impact on heart.

5) Asphyxiants

These kinds of poisons affect lungs. Fume or gases such as carbon dioxide, carbon monoxide and coal gas etc. fall under it.

6) Miscellaneous Class

The scope of poison is much wider based on its action, production and effect upon the organism. One could not make conclusive classification of all poison because every substance is itself a poison. Numbers of other classes of poison could be found in the scope of toxicology such as narcotic drugs, analgesics, tranquilizer, psychotropic substance, stimulant, hallucinogens etc.

3. Types of Effects Produced by Poisons

Effects produced by poison depend upon the nature, quantity and exposure time of poison. Sometimes effect may be acute or chronic. Generally, poisons show effect in three ways:⁷

Local effect: If minor effects are produced at the site of affected skin area, it is known as local effect. It may be produced instantly after contact of poisonous substance into skin. Corrosive poisons produce usual local effect.

Remote effect: Remote effect requires some time for absorption of poisons by circulatory system. Symptoms begin to appear after absorption and distribution of poison into different visceral parts through circulatory system. Neurotic poisons such as opium, psychotropic substance, narcotic drugs, and tranquilizer have remote effects.

Both local and remote effect: Some poisons produce local and remote effect simultaneously such as carbolic acid.

Causes of Modifying the Effect of Poisoning

There is no uniformity in effects produced by the poison. Following factors modify the effect of the poisons:

⁷ Nageshkumar G Rao, Textbook of Forensic Medicine and Toxicology, 419 (2nd ed. 2010).

- a) **Quantity or dose:** Degree of toxicity increases with increase in quantity. Toxicity decreases after excessive vomiting such as in case of arsenic (high dose leads death by shock without irritation symptoms (IS), moderate dose produces IS and small dose produces therapeutic action).
- b) **Form:** Form of poison also modifies the rate of effect. Poison acts most rapidly in gaseous, less in liquid and further less in solid form. Chemicals combination of acid such as silver nitrite acid and hydrochloride acid are strong poison. However, chemical combination of silver nitrite and hypochlorous acid forms silver chloride, an insoluble state which is harmless. A substance may be harmless in its metallic state (e.g. Arsenic) but its salt may be toxic.
- c) **Mechanical combination:** Mechanical combination of poison with inert substances may alter the action of poison. For e.g. strong dose of concentrated mineral acid produces corrosive action but same dose largely diluted with water is harmless. Similarly, Alkaloids when taken with animal charcoal, fail to act.
- d) **Route or mode of administration:** The rapidity in action of poison depends upon the route or mode of administration through which poison is taken. Rectal dose is twice and hypodermic dose is four times more rapid than oral dose. The lethal dose of poison is ten times maximum than medical dose. The rate of absorption of poison by the body is variable with the alimentary canal. The absorption is hastened if stomach is empty, poison is soluble in stomach contents and during gastroenterostomy (that is formation of new opening below stomach and intestine). Simultaneously, the rate of absorption is delayed under sleep, necrosis and trauma that causing gastrointestinal stasis. The skin is known as a bad absorptive organ.

c) **Condition of the body:** The effect of poisoning also depends upon following facts:

- 1) **Age:** Poisons have greater effect at the two extremes of age i.e. child and old age.
- 2) **Idiosyncrasy:** It refers inherent hyper sensitivity of particular human being.
- 3) **Habit:** It may have positive or negative effect with poison. Regular habit may increase tolerance towards certain poisons especially in addicts. For e.g. barbiturates, alcohol, cocaine etc.
- 4) **State of health:** A person with good health tolerates poison better. Simultaneously, even an ordinary dose may be fatal during diseased condition or general inability or senility (weakness due to old age). 30% of blood saturation of carbon monoxide is fatal causing coronary heart disease. Larger dose of opium in tetanus vaccine or delirium and strychnine in paralysis vaccine acts as medicine and do not cause severe damage to the body. Similarly, small dose of drugs like opium in granular kidney and bronchial asthma disease or mercury in chronic nephritis disease may produce serious harm and even death.
- 5) **Sleep and intoxication:** The action of poison is delayed if a person sleeps after taking poison or takes poison in an intoxicated condition.
- 6) **Cumulative effect:** Poisons that are eliminated slowly from the body if given in repeated doses for long time, produces chronic poisoning such as arsenic, Hg, Pb, barbiturates, digitalis etc.

4. Routes of Poison Administration

Routes of administration of poison refer the ways through which poisons are entered into human body. Administration through mouth is common method of poison administration as swallowing of liquid poisons. Various other routes of poison administration are recognized in medical science and frequently practiced as per the requirement of effect to be produced in the human body. Modi has grossly categorized routes in two different types- external (Oral, Sublingual- i.e under tongue, and per rectum) and parenteral (IV and IM) routes.⁸

Former route includes intake process while later includes route created by injecting substance through penetration like use of syringe.

Another medico legal author has classified routes as oral, hypodermic, intramuscular, intravenous, per-rectal, per vaginal, inhalation etc.⁹ major common routes of poison administration are as follows:

Oral cavity: It refers intake of any poison through mouth either by swallowing or chewing. Tablet drugs, liquid drugs are administered through oral cavity.

Inhalation: Inhalation of gaseous substance, smelling of drugs fall under this rout. For e.g. inhalation of ammonia.

Intravenous: Application of needle or pointed apparatus is needed to inject poison to vein. Use of intravenous route is more preferred than oral cavity if the treatment procedure requires rapid poison effect to patient.

Subcutaneous: The injection is targeted just below the skin at the fatty tissue.

Intra muscular: The poison is administered through injection into body muscles- especially at arms, thigh, and buttock.

⁸ Supra note 5 at 13

⁹ Supra note 7

5. Chemical Analysis & Modern Analysis Techniques

There are numbers of techniques for qualitative analysis (purity, composition, chemical concentration) and quantitative analysis (amount/ portion of poison) of poisonous substances. Such substances may be in the form of any substance, liquid, gases- organic, or inorganic.

Chemical analysis of poison helps to trace chemical composition of any poison, their molecular formula that differentiates a poison from another poison. Laboratory examination of poison helps ascertain peculiar nature of such poison, symptoms produced by it when administered in an organism, and method to reduce their harmful effect in order to save life.

In order to perform highly credible qualitative and quantitative analysis of poisons, laboratory must have two basic requirements: (a) Qualified human resource to conduct poison analysis. They should be well trained or taught about analytical toxicology. (b) The laboratory must be well accredited or well equipped with modern analytical instruments.

The branch of analytical toxicology has focused on techniques of analysis (detection of both quality and quantity). This analysis is possible through comparison of poisons. Forensic tests are usually based on comparison. For example, if one needs to test whether a disputed sample is metacide or not, the examiner needs a metacid simple as well. Thus, for all analytical techniques/ procedure, we usually need two samples as standards- (a) Control sample (known sample), and (b) disputed/suspected sample. Some validated methods however are already validated using standard controls.

Analysis process of poison starts after availability of both

these samples. Comparison can be made through several methods or technique of test. Some methods of test are as follows:

1. **Field Test:** Field test refers the test done by Forensic expert at scene of crime. This method is not yet practiced in Nepal. Field test for analysis of poison comes under crime scene investigation. It is widely practiced in developed countries. This test is more accurate and credible if mobile laboratories are well equipped and accompanied by toxicology expert, as the test is carried upon a fresh sample present at scene of crime. This test could not be performed if there is lacking of all necessary equipments.
2. **Chemical Test:** The chemical test varies in poison for different group. For example, to test for the presence of a phosphate group poison, following chemical tests are done:
 - I. **Phosphide Test:** To test rat poison i.e. Zinc (Zn) or Aluminum (Al) phosphide test is done. The test only shows presence or absence of phosphate group poison.
 - II. **Confirmative Test:** After Phosphide test, we need to confirm it. The phosphate is oxidized and formation of blue colour salt indicates presence of Zn or Al.
 - III. **Filter ash test:** Then this test ultimately determines whether the poison used was Al phosphate or Zn phosphate.
3. **Instrumental Method:** This method is used for quantification of insecticides and is more common in Nepal. Example of some test under it:
 - a. High pressure liquid chromatography (HPLC) test
 - b. Gas liquid chromatography (GLC) test
 - c. Ordinary titration method
 - d. Haemoxymeter to quantify carbon monoxide in blood

Beside these, there are other general chemical test method. TLC (Thin Layer Chromatography) method is one of them. It is a best method for qualitative analysis. In TLC, two samples, control sample and suspected sample are taken and a drop of both sample are kept at uniform level of TLC paper. Then the Retardation Factor (RF) value is determined and from table or book, one could analyze the specific poison. In TLC method, the poison is extracted from viscera and dried and then made solution and test (TLC) is conducted. This method is considered as reliable method for qualitative analysis. Nevertheless, this method does not show any poison if extraction was defective or inefficient.

[TLC Test Procedure : See figure 17.1 in figure section]

6. External & Internal Examination of Body in Poisoning

A) Appearance in Living Person

Medical practitioners frequently face cases of poisoning where victims are still alive and need treatment for saving life. In such case, the appearance of victim depends upon nature of poisoning either acute or chronic.¹⁰

- a) **Acute poisoning:** In acute poisoning, symptoms appear suddenly after intake of poisonous substance like rat poison. The symptoms rapidly increase in severity and are followed by death or recovery. Poison can be detected in the ingested food, medicine and fluid, vomit or gastric lavage, blood, urine or stool etc. of the victim.
- b) **Chronic poisoning:** Chronic poisoning develops symptoms gradually and insidiously. There may be remission or

¹⁰ Supra note 3 at 8,9

complete disappearance of symptoms after removal of patient from his poison surroundings. Poison could be detected in food, medicine, fluid administered or in the vomit, urine, or stool of the victim. The main symptoms in chronic poisoning are usually malaise, gradual deterioration of health, or repeated attacks of undigested gastrointestinal irritation. Chronic poisoning is taken as suspicion of homicidal poisoning.

B) Appearance in Dead Body

Post mortem examination of the poisoning simultaneously requires chemical analysis, circumstantial evidences, and history or background of death in order to provide clear fact.

a) External examination

External examination of death due to poison may provide following general signs:

- Some peculiar smell may be resulted from the body due to effect of strong poison such as in case of carbolic acid, chloroform and opium.
- Natural orifices may show presence of poisonous substance or signs of corrosive irritation.
- Small bubbles of forth may be found at nose and mouth.
- Body parts, clothes may show stain marks of poison drops or vomit.
- Marks of injection may be found if the poison is administered intravenously.
- Marks of violence, abrasion, contusion or other injury caused by assailant or due to struggle after poisoning, may be seen.

b) Internal examination

In alimentary canal, signs of corrosive and irritant poisons are likely to be found if the poison was corrosive and irritant in nature. However, in case of poisons other than corrosive and irritant, the life may be destroyed easily without leaving any naked symptoms (visible to normal eye). Corrosive and irritant poisons mainly produce effect in digestive tract. It may show following signs:¹¹

- Mucous membrane redness marks may be seen at the cardiac end and at the greater curvature of stomach. Sometimes different discoloration may be seen due to other poisons such as yellow color may be seen in case of nitric acid.
- In case of application of alkaline corrosive, mucous membrane of the intestines may show softness especially at cardiac end and the greater curvature. In contrary to this feature, poisons such as carbolic acid produce hardening and shrinking effect in mucous membrane.
- Ulceration is found at greater curvature of the stomach.
- Perforation is rare in corrosive poisoning. If, it is produced then features such as larger size, ragged edge, irregular and lacerated coast are seen.

Other types of poison besides corrosive and irritant may not produce similar form of symptoms and may even lead to death without showing any remarkable general features. Thus, the required viscera must be removed in prescribed quantity and forwarded to chemical examiner for analysis. Beside this, other forms of examination are also relevant.

1. Chemical analysis: Analytical detection of poison in the parenchyma of the organs of the body is most important

¹¹ Supra note 5 at 19-22

- proof of poisoning. Certain chemical tests are carried over the suspected matters or samples. Some poisons may be pure chemicals and others complex natural products.
2. Experiments on suitable animals: The suspected food, medicine, fluid or the poison extracted from the viscera are fed to domestic animals such as dog or cat. These animals are affected in the same way as human beings.
 3. Moral and circumstantial evidence: Clues regarding the recent purchase of poison by victim or accused, his or her behavior, conduct of those looking after the victim, suicidal note, history of quarrel and financial problems etc may provide reliable information.

7. Collection of Viscera & Other Samples from Human Body

Detection of poison in the excretions, blood and other viscera are strong evidence of poisoning. Thus, viscera and other samples from human being suspected of poisoning are important. Following volume of viscera are needed to be collected or preserved for poison examination:¹²

- a) If suspect of poison is alive:
 - First Stomach wash – 500 ml.
 - Vomit – 100 ml. (or as much as received)
 - Urine – 100 ml.
 - Blood with preservative (EDTA/NaF) - 10 ml.
 - Blood without preservative – 10 ml.
- b) If the suspect of poison is dead

¹² Hand Book of Forensic Science, Central Police Forensic Science Laboratory

- Stomach with its contents – Whole
- Liver – One lobe (Half)
- Small intestine & its content – 2 feet
- Heart – 100 gm.
- Lungs- One lobe (Half)
- Kidney – One / Two
- Spleen
- Brain – Whole
- Blood – 50 ml.
- Bones (femur) – 100 gm.
- Hair and nail as much as received
- Skin

8. Medico Legal Importance of Poisoning

Medico legal cases associated with toxicology may be suicidal, homicidal or accidental. Medical practitioners are often confronted with question to estimate whether the particular case of poisoning is accidental, suicidal or homicidal. In such case, they take assistance of examination of numerous aspects. Some importances of examination of poisoning are as follows:

- a) It is important to distinguish whether a case of poisoning is accidental, suicidal or homicidal. Accidental poisoning is rare in adult. However, children are frequently poisoned accidental due to lack of their information regarding the nature of substance and effects produced after entry into the body. Industrial hazards may produce poisonous effect upon workers. Crop farmer spraying pesticide in the field without taking precaution may be poisoned accidentally.

- b) Suicidal poisoning has been growing as common method of suicide these days. Housewife, victim of domestic violence, love failure person, heavily debt burdened farmers etc. are more vulnerable to commit suicide through poisoning. Poisons having easy market availability such as metacide, pesticides, rat poison, heavy dose of sleeping tablet, heavy dose of opium etc. are more commonly used for suicide. In a case,¹³ defendant mother administered poison named Tiger-10 on herself to commit suicide. Accordingly, she gave her children poison named, Delfin, with intention to release them from future trouble after her death.
- c) Homicidal administration of poisons is more commonly used to kill children and women. Suicidal and homicidal poisoning is needed to be distinguished in order to determine culpability of offender. It may be hard to differentiate suicidal and homicidal poisoning because both produce same nature of symptoms. Presence of violence marks around the body such as contusion, abrasions, and redness of tissues may be present in homicidal poisoning.
- d) A fetus may have toxic effect (teratogenicity) when mother is exposed to toxic agent during pregnancy.
- e) Food poisoning should be differentiated from other forms of poisoning.

¹³ *Government of Nepal v. Numa Bajgain* 2072, D.N. 9467